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DEPARTMENT OF PHYSICS AND ASTRONOMY

UNIVERSITY OF MASSACHUSETTS

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STUDIES OF RADIATIVE TRANSFER IN PLANETARY ATMOSPHERES

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Current research

Schloerb and E. Gerard (Observatoire de Meudon) completed a paper modeling cometary emission in the 18-cm OH transitions, with specific applications and predictions for Comet Halley. Observations of the OH A-doublet transitions are expected to yield significant results for cometary science in a number of areas, including kinematics in the coma and measurement of the production rate of the OH parent molecules (water) at times when optical observations are not feasible. Polarimetry, coma mapping, and observations of the occultation of background sources are also discussed.

Schloerb and students C. McGunigle and R. Molloy completed analysis of OH 18 cm observations of Comet Crommelin which were obtained as part of the International Halley Watch trial run. Comparisons of the results at 1667 and 1665 MHz indicate that the coma is optically thin at these transitions. A gas production rate of approximately $7(10)^{27}$ molecules per second is obtained, which is consistent with other radio results and with the behavior of the OH

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radio lines in previous comets. The line profile appears to be double peaked, probably indicating the presence of jets of material in the coma.

Irvine, Karttunen, and Lumme (visiting from the University of Helsinki) continued the study of radiative transfer in rough and porous media. The theory developed requires specification of three additional parameters to complement the single scattering albedo and single particle phase function which enter the classical, plane-parallel radiative transfer theory. The theory reduces to the classical case in the appropriate limits.

Swade is continuing study of the relatively nearby cold, dark interstellar cloud L134N. It is thought that molecular clouds of this type may be the sites for formation of solar type stars, and conceivably associated planetary systems. The kinematics of the cloud have been mapped via observations of the $J=1-0$ transition of ^{13}CO , supplemented by C^{18}O observations of the inner core. Several condensations of a few solar masses are apparent. Significant chemical differences appear to exist between some of these condensations, and the reasons for this are being investigated.

Following the summer observatory shutdown, Schloerb has resumed the program of CO monitoring of Venus and Mars at the FCRAO. Local observations of the $J=1-0$ and $2-1$ transitions will be supplemented with data on the $J=3-2$ transition obtained at the Multi-Mirror Telescope in Arizona.

Schloerb and graduate student D. Swade completed analysis of 3.4 mm maps of the lunar surface obtained with the Five College Radio Astronomy Observatory (FCRAO) 14 m radio telescope. The new moon map shows thermal anomalies associated with such surface features as the crater Copernicus, Mare Imbrium, Mare Nubium, Mare Serenitatis, and Mare Tranquillitatis. Such anomalies are suppressed in the full moon map. Since the continuum radiation emitted by the moon depends on the thermal and electrical properties of the

lunar regolith, these features are indicative of variations in regolith properties across the lunar surface.

Irvine and Schloerb attended the General Assembly of the International Scientific Radio Union to organize a session on radio science of comets. Irvine, Schloerb and Swade attended the annual meeting of the Division for Planetary Sciences of the American Astronomical Society and presented three papers describing research supported by this grant.

Articles with grant support published during the period of this report:

- 1) Irvine, W.M., Z. Abraham , M. A'Hearn, W. Altenhoff, Ch. Andersson, J. Bally, W. Batrla, A. Baudry, D. Bockelee-Morvan, G. Chin, J. Crovisier, I. de Pater, D. Despois, L. Ekelund, E. Gerard, T. Hasegawa, C. Heiles, J.M. Hoilis, , W. Huchtmeier, N. Kaifu, R. Levreault, C.R. Masson, P. Palmer, M. Perault, L.J. Rickard, A.I. Sargent, E. Scalise, F.P. Schloerb, S. Schmidt, , A.A. Stark, M. Stevens, P. Stumpff, E. Sutton, D. Swade, M. Sykes, B. Turner, C. Wade, M. Walmsley, J. Webber, A. Winnberg, and A. Wootten, "Radioastronomical Observations of Comets IRAS-Araki-Alcock (1973d) and Sugano-Saigusa-Fujikawa (1983e)", Icarus, **60**, 215 (1984).
- 2) Lumme, K. and Irvine W.M., "Azimuthal Variations in Saturn's A Ring", in Anneaux des Planetes-Planetary Rings (IAU Colloq. 75), ed. A. Brahic (Cepadues-Editions, Toulouse, France), pp. 87-91.
- 3) Thompson, W., Van Blerkom, D., and Irvine, W.M., "A Model Containing "Blobs" for the A ring of Saturn", in Anneaux des Planetes-Planetary Rings (IAU Colloq. 75), ed. A. Brahic (Cepadues-Editions, Toulouse, France), pp. 93-98.
- 4) Lumme, K., Karttunen, H. and Irvine, W.M., "Radiative Transfer in Horizontally Inhomogeneous Media", Bull. A.A.S. **16**, 669 (1984).
- 5) Schloerb, F.P., C.A. McGunigle and A.R. Molloy, "Radio Observations of OH in P/Crommelin", Bull. A.A.S. **16**, 645 (1984).
- 6) Swade, D.A. and F.P. Schloerb, "Millimeter Radio Observations of the Moon", Bull. A.A.S. **16**, 667 (1984).

Articles with grant support currently in press:

- 1) Bockelee-Morvan, D., J. Crovisier, A. Baudry, D. Despois, M. Perault, W.M. Irvine, F.P. Schloerb, and D. Swade, "Hydrogen Cyanide in Comets: Excitation Conditions and Radio Observations of Comet IRAS-Araki-Alcock (1983d)", Astron. Astrophys., in press (1984).
- 2) Lumme, K. and E. Bowell, "Photometric Properties of Zodiacal Light Particles", Icarus, in press (1985).

- 3) Lumme, K., H. Karttunen and W.M. Irvine, "Roughness of the Lunar Soil", Earth, Moon, Planets, in press (1984).
- 4) McGunigle, C.A. and W.M. Irvine, "Comets and the Origin of Life", Bol. Soc. Portuguesa Quim., in press (1985).
- 5) Schloerb, F.P. and E. Gerard, "Models of Cometary Emission in the 18 cm OH Transitions: the Predicted Behavior of Comet Halley", Astron. J., submitted.

Future Plans

Schloerb, student R. Molloy, and I. de Pater (University of California at Berkeley) are investigating possible occultations of background radio sources by the coma and tail of Comet Halley. Radio frequency observations of such occultations can in principle provide information on the electron density, magnetic field, and fluctuations in these quantities. Observations of previous comets have suggested the existence of such effects, but the results have not been conclusive. Several excellent opportunities appear to exist in the case of Comet Halley.

Swade will continue his investigations of the nearby interstellar molecular cloud L134N. It is hoped that such investigations will shed light on the formation of solar type stars. In addition to studying the physical properties and kinematics of such clouds, we hope to relate their chemical composition to that of the presolar nebula and hence to the composition of comets. In this connection it is interesting to note that there is evidence for significant chemical variations within the cloud, the origin of which is not understood at this time.

Theoretical studies of radiative transfer relevant to solar system objects will continue. Lumme and Irvine are working on a generalization of the Lumme-Bowell theory describing multiple scattering in planetary regoliths. Schloerb is studying the maximum entropy technique for inverting spectral line profiles in order to deduce temperatures and mixing ratios for trace constituents in

planetary atmospheres.

Observations of carbon monoxide in the atmospheres of Venus and Mars at the University of Massachusetts - operated FCRAO will be complemented by higher frequency observations at the Multi-Mirror Telescope in Arizona. Receivers built at the University of Massachusetts will be taken to the MMT during the winter to observe the J=3-2 CO transition, and thus provide additional important data on the carbon monoxide mixing ratio in the Venus upper atmosphere.

We are investigating the possibility of detecting trace atmospheric constituents in the atmospheres of the outer planets via radio astronomical observations.

Personnel

H. Karttunen, Visiting Scholar at the University of Massachusetts from the University of Helsinki, returned to Finland during the period of this report. Graduate students L. Garman, J. Morgan, and R. Seamans worked part time during the summer on projects at the FCRAO designed to improve the efficiency of the planetary CO monitoring programs. J. Mortarelli worked for one month as a computer programmer.

Financial Report

A detailed financial report will be submitted by the Office of the Treasury, University of Massachusetts.

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